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Dialysis Membrane with Improved Removal of Middle Molecules

Claims

1. A hydrophilic, water-wettable, semipermeable hollow-fibre membrane for blood purification comprising a synthetic first polymer, the hollow-fibre membrane possessing an open-pored integrally asymmetric structure across its wall, a porous separating layer of thickness between 0.1 and 2 µm on its inner surface facing the lumen, and an open-pored supporting layer adjoining the separating layer, and having an ultrafiltration rate in albumin solution in the range of 5 to 25 ml/(h·m²·mmHg), characterised in that the hollow-fibre membrane, in the absence of additives stabilising the pores in the membrane wall and after prior drying, has a maximum sieving coefficient for albumin of 0.005 combined with a sieving coefficient for cytochrome c that satisfies the relation

$$SC_{CC} \geq 5 \cdot 10^{-5} \cdot UFR_{Alb}^3 - 0.004 \cdot UFR_{Alb}^2 + 0.1081 \cdot UFR_{Alb} - 0.25$$

2. Hollow-fibre membrane according to Claim 1, characterised in that it has a sieving coefficient for cytochrome c that satisfies the relation

$$SC_{CC} \geq 5 \cdot 10^{-5} \cdot UFR_{Alb}^3 - 0.004 \cdot UFR_{Alb}^2 + 0.1081 \cdot UFR_{Alb} - 0.12$$

3. Hollow-fibre membrane according to one or both of Claims 1 and 2, characterised in that it also comprises a hydrophilic second polymer.

4. Hollow-fibre membrane according to one or both of Claims 1 and 2, characterised in that the synthetic first polymer is a hydrophobic first polymer and the hollow-fibre membrane also comprises a hydrophilic second polymer.

5. Hollow-fibre membrane according to Claim 4, characterised in that the hydrophobic first polymer is an aromatic sulfone polymer such as polysulfone, polyethersulfone, polyphenylenesulfone or polyarylethersulfone, a polycarbonate, polyimide, polyetherimide, polyetherketone, polyphenylene sulfide or a copolymer or mixture of these polymers.

6. Hollow-fibre membrane according to Claim 5, characterised in that the hydrophobic first polymer is a polysulfone or a polyethersulfone.

7. Hollow-fibre membrane according to one or more of Claims 3 to 6, characterised in that the hydrophilic second polymer is polyvinylpyrrolidone, polyethylene glycol, polyvinyl alcohol, polyglycol monoester, polysorbate, carboxymethylcellulose, or a copolymer of these polymers.

8. Hollow-fibre membrane according to one or more of Claims 1 to 7, characterised in that the supporting layer extends from the separating layer across essentially the entire wall of the hollow-fibre membrane and has a sponge-like structure that is free from finger pores.

9. Hollow-fibre membrane according to one or more of Claims 1 to 8, characterised in that it has a maximum sieving coefficient for albumin of 0.003.

10. Hollow-fibre membrane according to one or more of Claims 1 to 9, characterised in that a polyelectrolyte with negative fixed charges is physically bound in the separating layer.

11. Hollow-fibre membrane according to one or more of Claims 1 to 10 with an ultrafiltration rate in albumin solution in the range of 10 to 25 ml/(h·m²·mmHg).

12. Method for producing a hydrophilic, water-wettable, semipermeable hollow-fibre membrane, comprising the following steps:
    a. preparing a homogeneous spinning solution comprising 12 to 30 wt.% of a synthetic first polymer and, if necessary, other additives in a solvent system,
    b. extruding the spinning solution through the annular slit of a hollow-fibre die to give a hollow fibre,
    c. extruding an interior filler through the central opening of the hollow-fibre die, the interior filler being a coagulation medium for the synthetic first polymer and comprising a solvent and a non-solvent for the synthetic first polymer,
    d. bringing the interior filler into contact with the inner surface of the hollow fibre to initiate coagulation in the interior of the hollow fibre and for formation of a separating layer on the inner surface of the hollow fibre and formation of the membrane structure,
    e. passing the hollow fibre through a coagulation bath to complete the formation of the membrane structure if necessary and to fix the membrane structure,
    f. extracting the hollow-fibre membrane thus formed, to remove the solvent system and soluble substances, and

g. drying the hollow-fibre membrane,

characterised in that the interior filler contains a polyelectrolyte with negative fixed charges, wherein the steps of the method are to be carried out in such a way that a hollow-fibre membrane according to Claim 1 is obtained with an ultrafiltration rate in albumin solution in the range of 5 to 25 ml/(h·m²·mmHg) and a maximum sieving coefficient for albumin of 0.005 combined with a sieving coefficient for cytochrome c that satisfies the following relation:

$SC_{CC} \geq .5 \cdot 10^{-5} \cdot UFR_{Alb}^3 - 0.004 \cdot UFR_{Alb}^2 + 0.1081 \cdot UFR_{Alb} - 0.25$

13. Method according to Claim 12, characterised in that the spinning solution also comprises 0.1 to 30 wt.% of a hydrophilic second polymer.

14. Method according to Claim 12, characterised in that the synthetic first polymer is a hydrophobic first polymer and the spinning solution also comprises 0.1 to 30 wt.% of a hydrophilic second polymer.

15. Method according to Claim 14, characterised in that an aromatic sulfone polymer such as polysulfone, polyethersulfone, polyphenylenesulfone or polyarylethersulfone, a polycarbonate, polyimide, polyetherimide, polyetherketone, polyphenylene sulfide, or a copolymer or mixture of these polymers is used as the hydrophobic first polymer.

16. Method according to one or more of Claims 13 to 15, characterised in that polyvinylpyrrolidone, polyethylene glycol, polyvinyl alcohol, polyglycol monoester, polysorbate, carboxymethylcellulose, or a copolymer of these polymers is used as the hydrophilic second polymer.

17. Method according to one or more of Claims 12 to 16, characterised in that the solvent system comprises a polar aprotic solvent.

18. Method according to one or more of Claims 12 to 17, characterised in that the polyelectrolyte is selected from the group of polyphosphoric acids, polysulfonic acids, or polycarboxylic acids.

19. Method according to Claim 18, characterised in that the polycarboxylic acids are homo- or copolymers of acrylic acid.

20. Method according to one or more of Claims 12 to 19, characterised in that the proportion by weight of the polyelectrolyte is 0.01 to 1 wt.% relative to the weight of the interior filler.